Jets & the Medium in PHENIX

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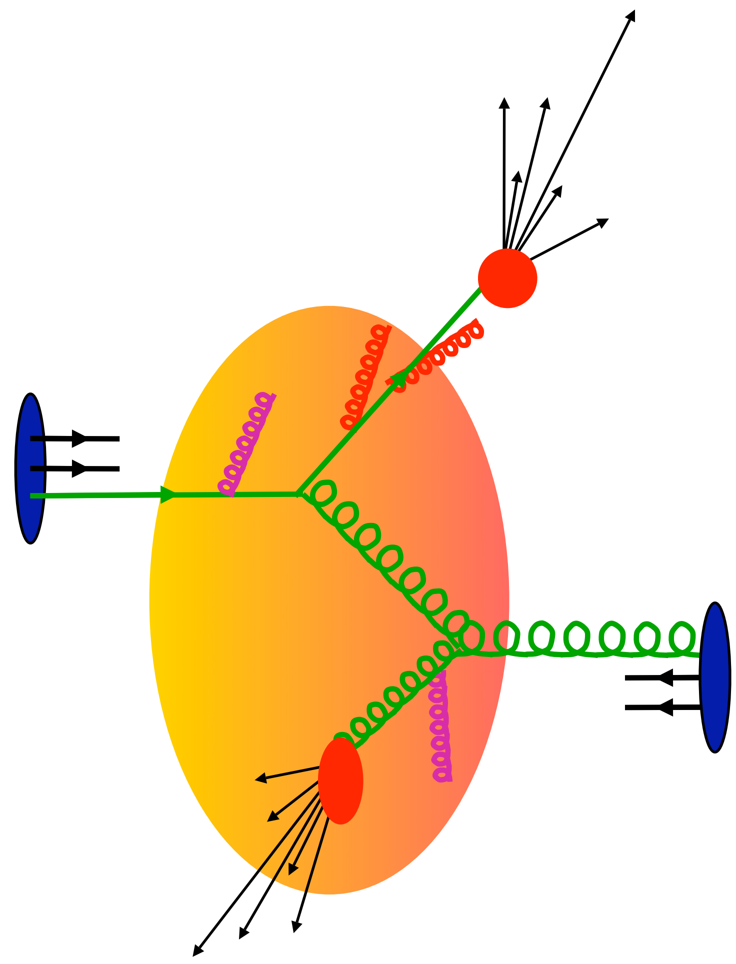
Jet Interactions with the Bulk Workshop

June 7, 2006

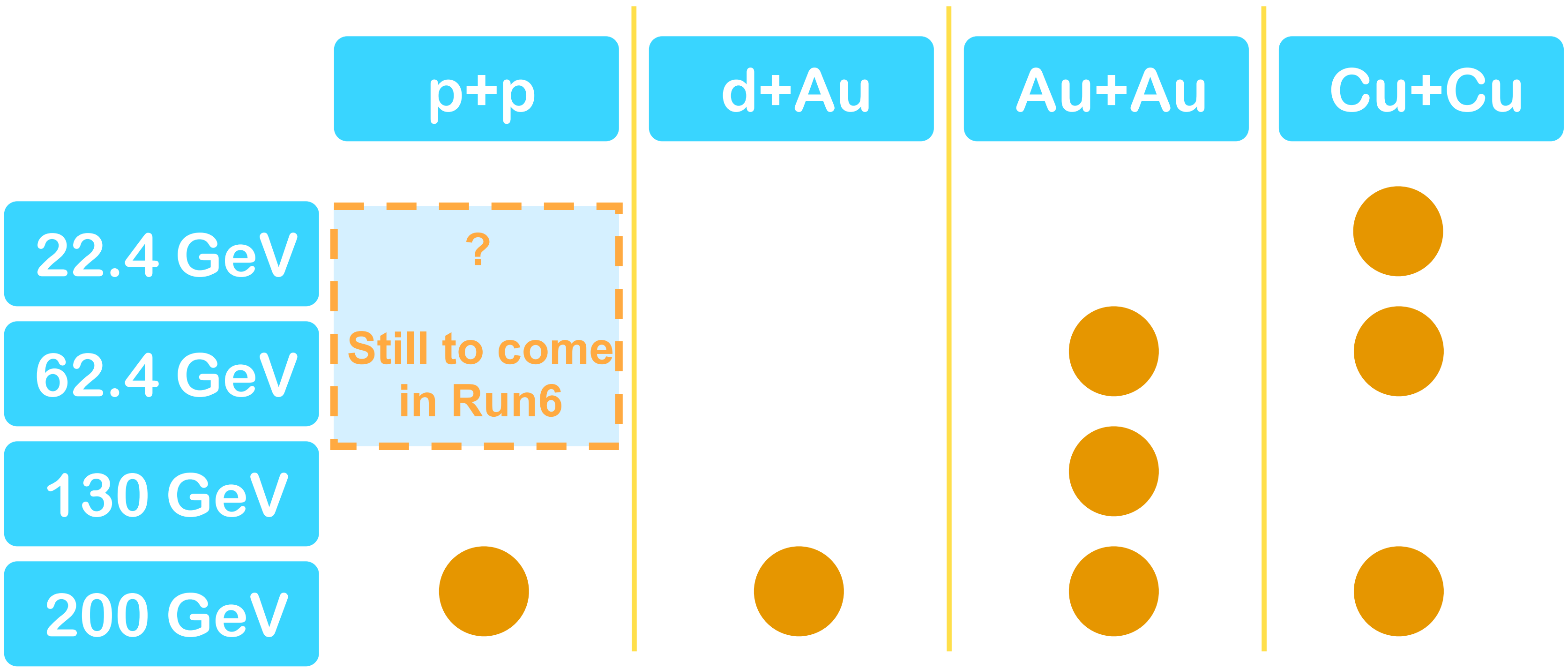
PHENIX

Why Jets?

- hard probes are calibrated→pQCD
- jets can be measured in heavy ions, pp, dAu, e^+e^-
- jet partons interact with the medium via the strong force
    - sensitive to entire lifetime of the system



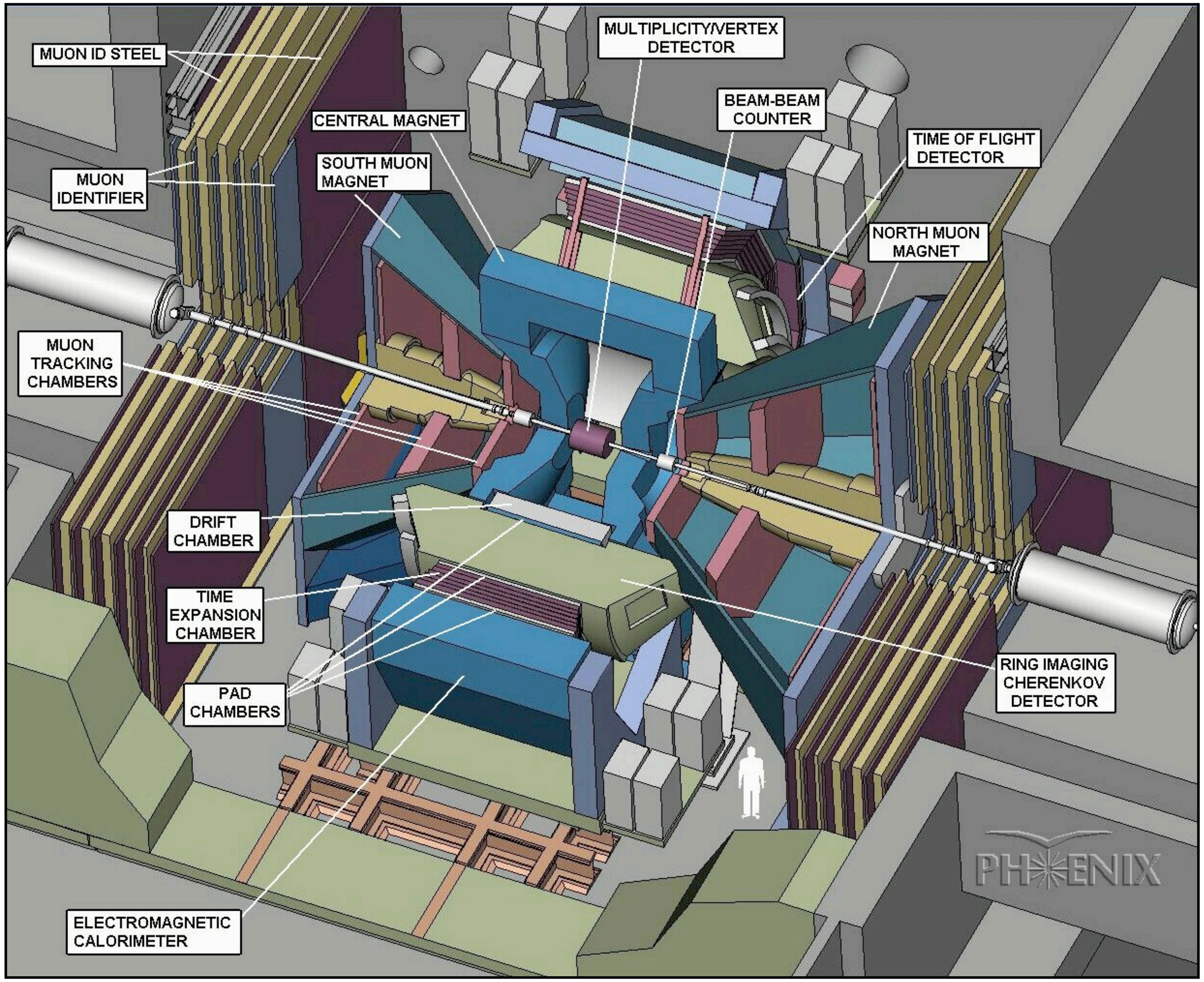
data on hand



Allows systematic studies as a function of system and energy

PHENIX

- PHENIX is optimized to study a wide variety of probes
- charged particle tracking
- EMCal ($e^{+/-}$, γ)
- particle ID over wide p_T range and large acceptance
- triggers for rare events



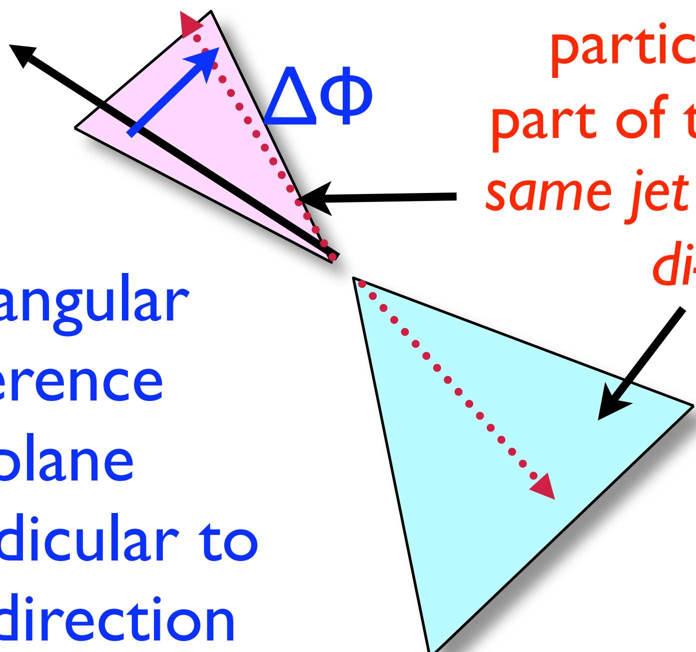
Outline

- **The Present**: Two Particle Correlations as a Tool
  - Away Side Correlations: Shape Modifications
  - Same Side Correlations: Recombination, Surface Emission
- **The Frontier**: Three Particle Correlations to Understand Shape Modifications
- **The Future**: Direct γ Correlations--The Whole Story
- **Conclusions**

Warning: This is only a part of the PHENIX data that fits the theme of this workshop

Two Particle Correlations

Trigger: rare “high” p_T particles
identify a hard scattering



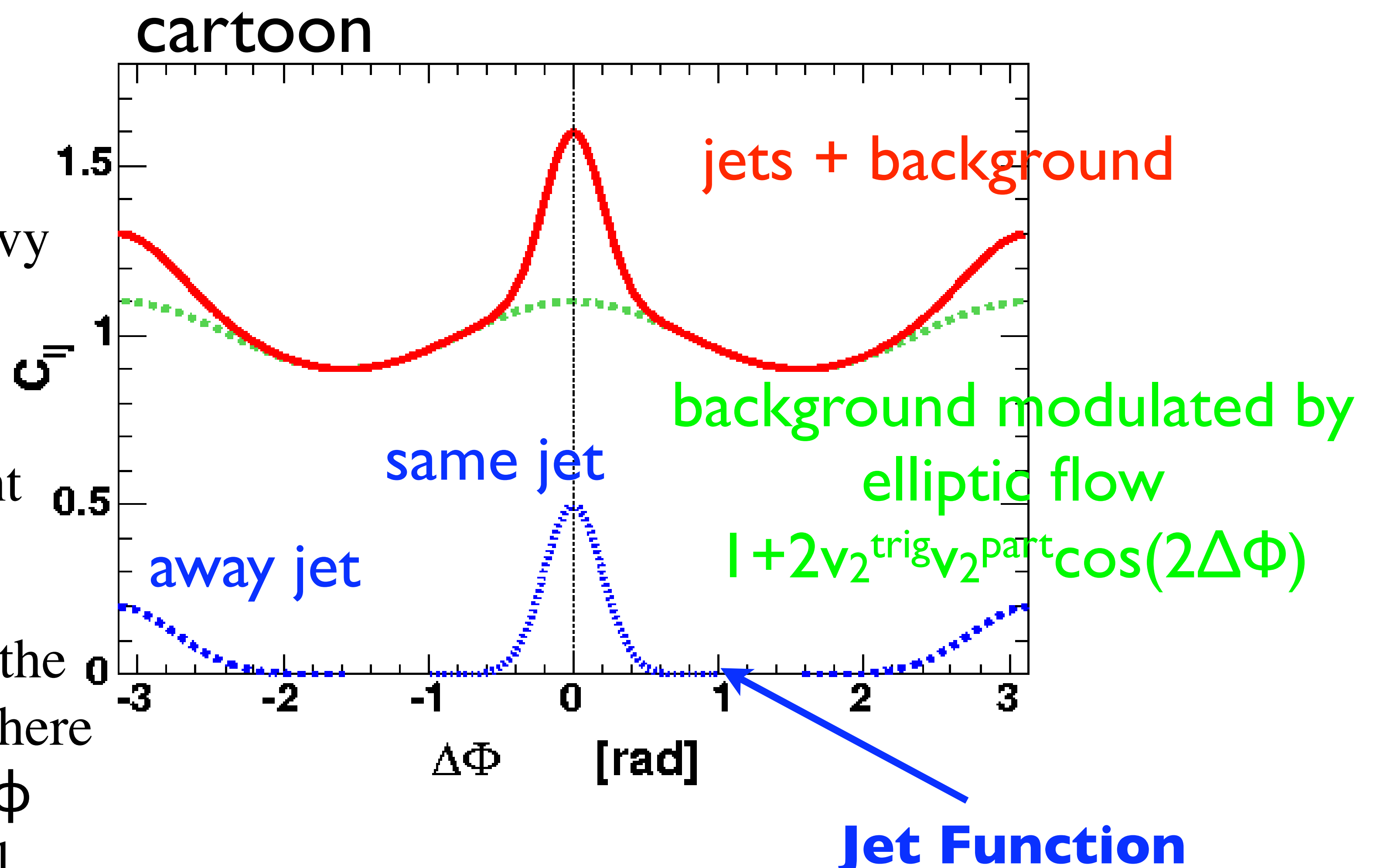
Partners: lower p_T particles part of the *same jet or di-jet*

ΔΦ: angular difference in plane perpendicular to beam direction

- identify jets statistically
  - triggers provide biased jets
- model independent
- works well in all collision systems at RHIC
- correct for non-uniform PHENIX azimuthal acceptance divide real Δϕ distributions by those from mixed events (contain no correlations)

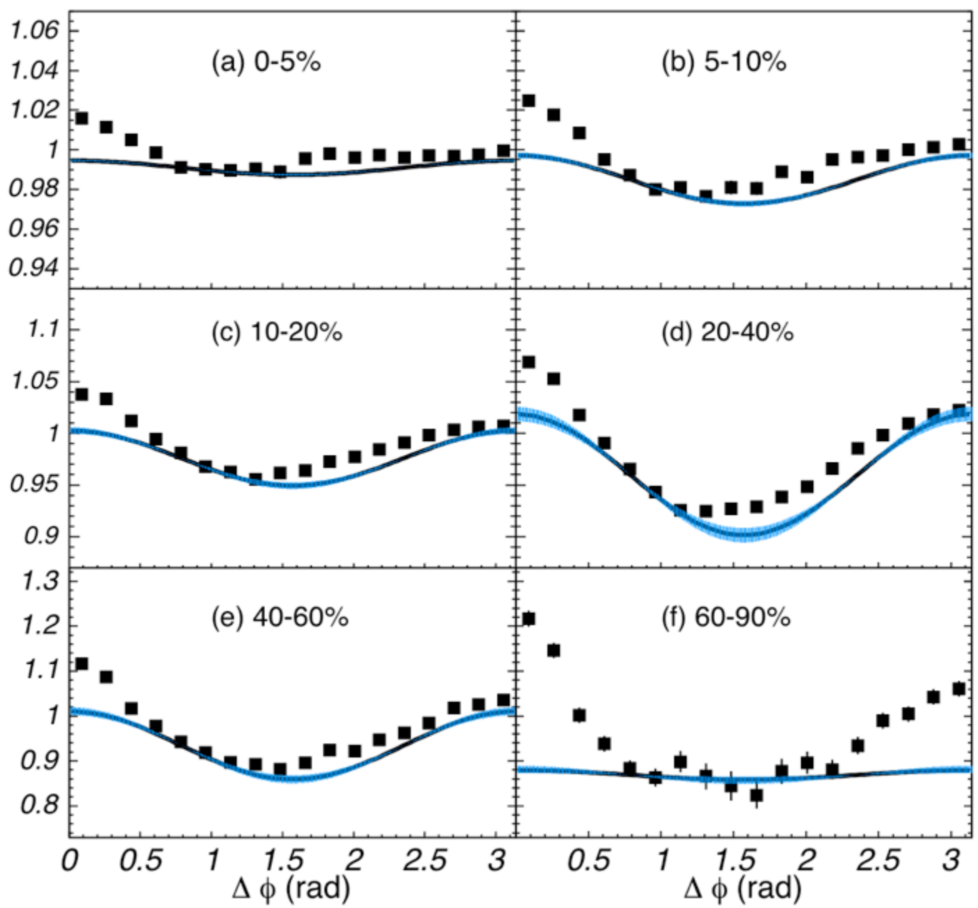
Finding the Jet Signal

- large combinatoric background in heavy ion events
  - due to the underlying event multiplicity
  - either calculate the rate or assume there is a region in $\Delta\phi$ where the signal doesn't contribute (ZYAM)

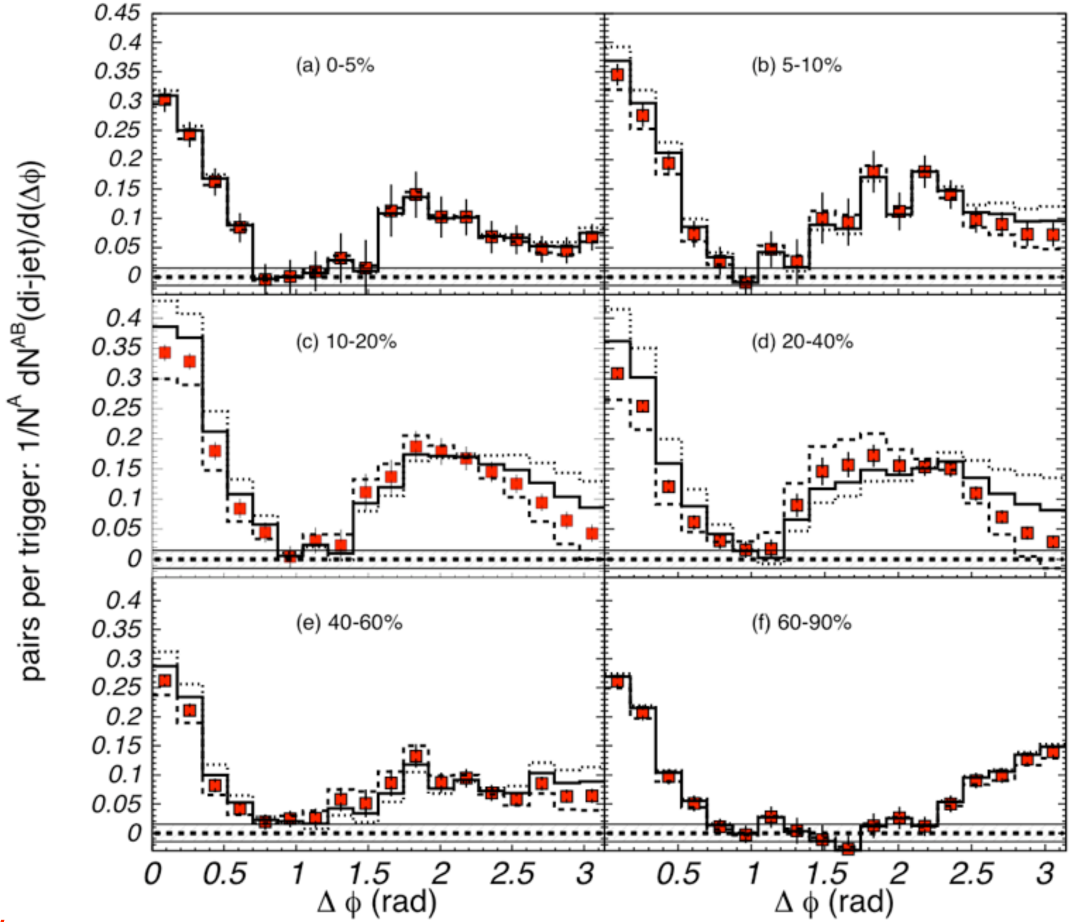


Jets at Intermediate p_T

Correlation Function



Flow Subtracted Jet Function



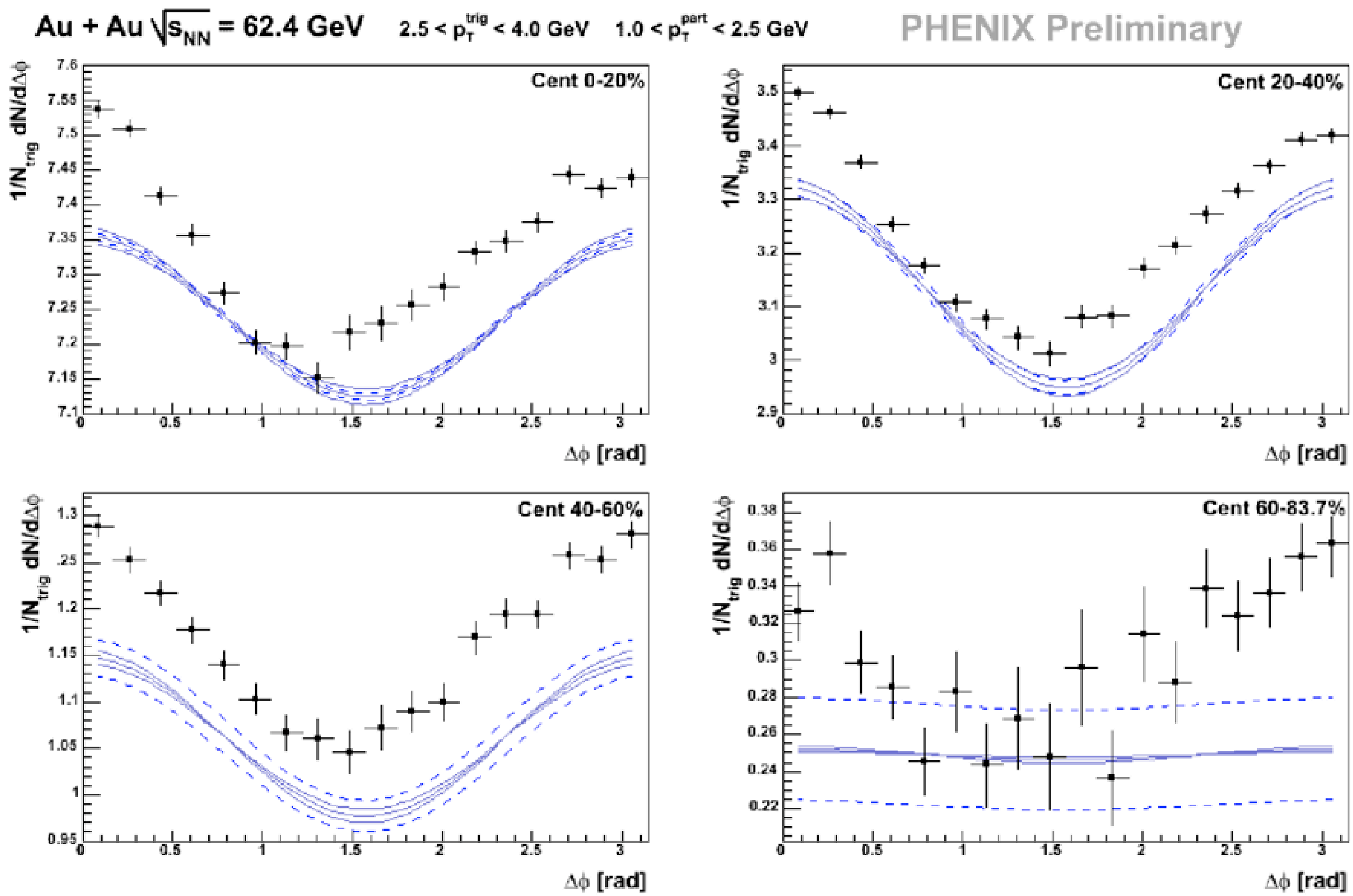
trigger: $2.5<p_T<4.0$ GeV/c
partner: $1.0<p_T<2.5$ GeV/c
charged hadrons

PHENIX, nucl-ex/0507004 submitted to PRL

AuAu 62.4GeV

trigger: 2.5<p_T<4.0 GeV/c
partner: 1.0<p_T<2.5 GeV/c
charged hadrons

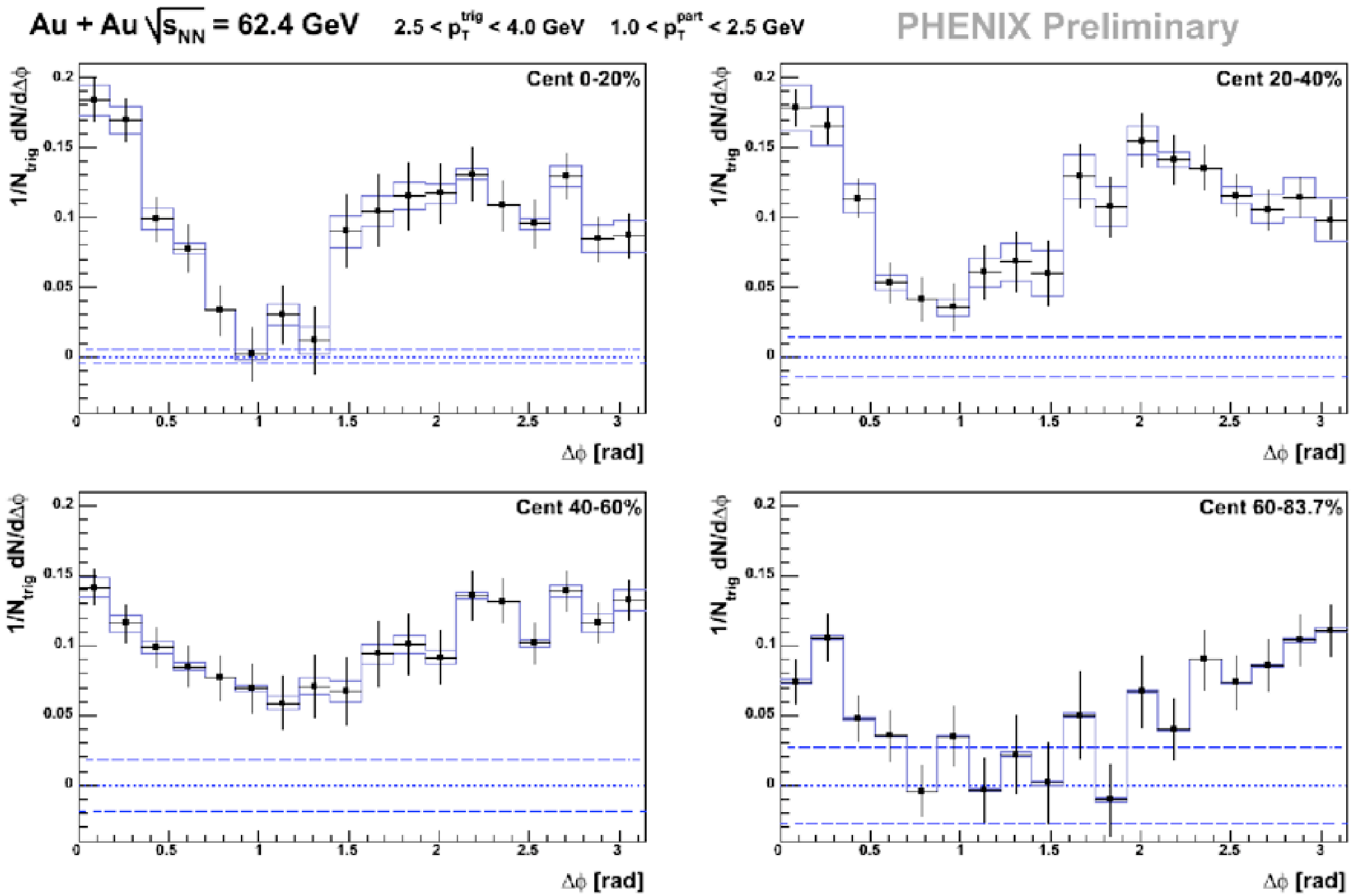
Correlation Functions



AuAu 62.4GeV

trigger: $2.5<p_T<4.0$ GeV/c
partner: $1.0<p_T<2.5$ GeV/c
charged hadrons

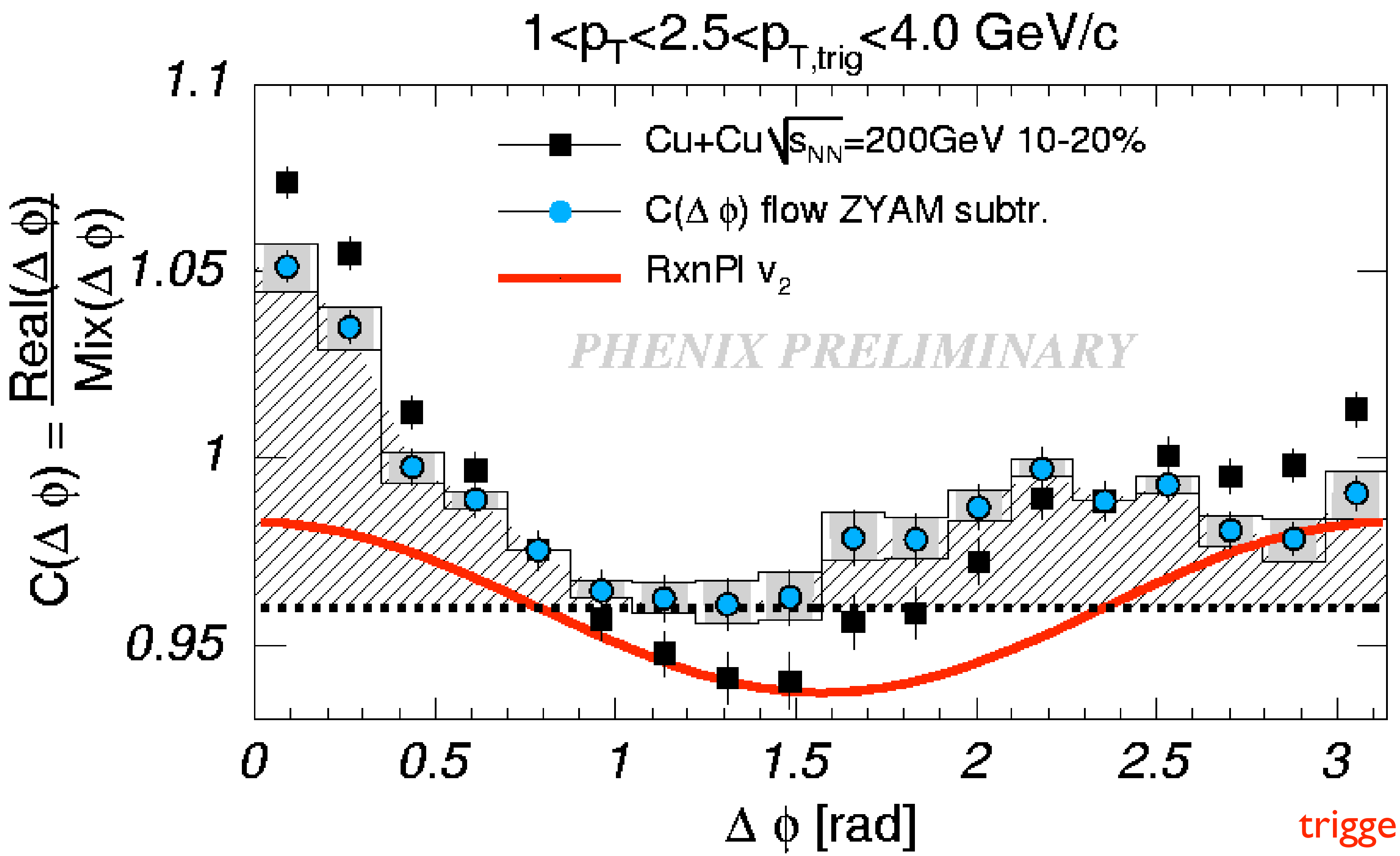
Jet Functions--v_2 Subtracted



away side still broad and flat in central events

normal shape in peripheral events

What about Cu+Cu?



Correlation function

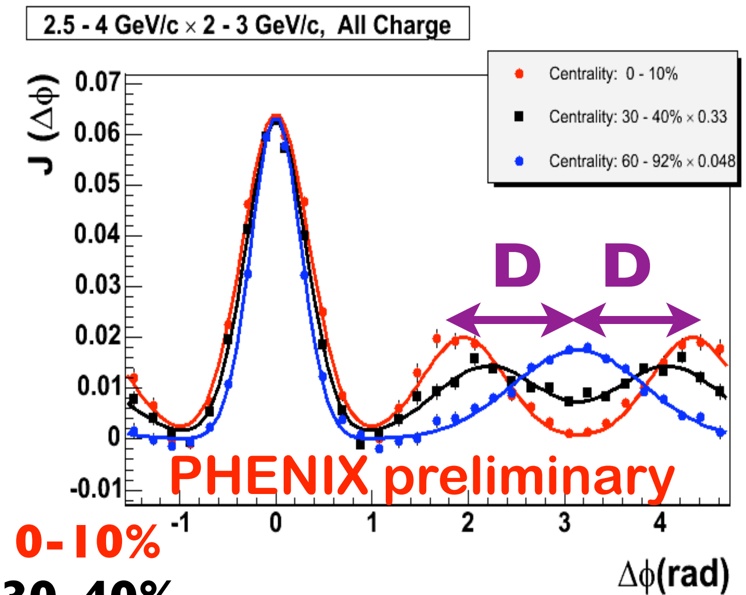
v_2 subtracted jet function flat or dip

trigger: $2.5<p_T<4.0$ GeV/c
partner: $1.0<p_T<2.5$ GeV/c
charged hadrons

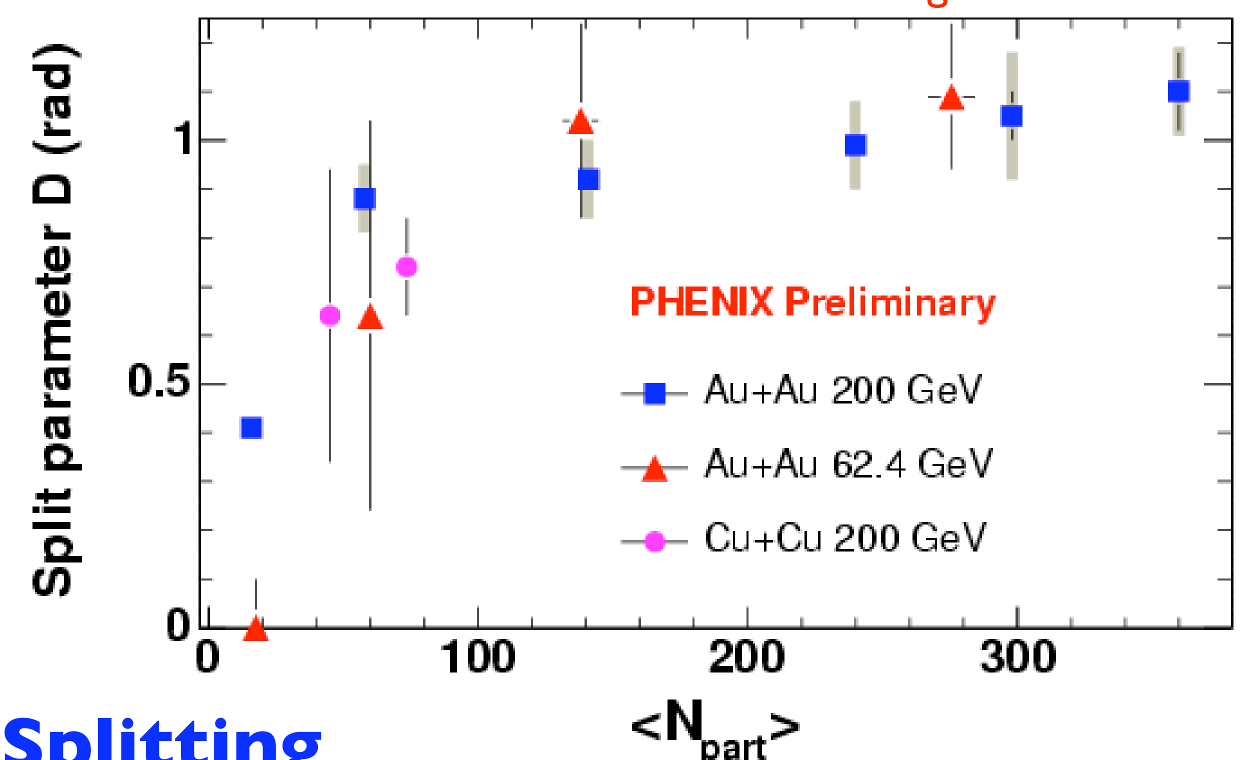
$N_{part} \sim 74$

The Split Quantified

trigger: $2.5<p_T<4.0$ GeV/c
partner: $1.0<p_T<2.5$ GeV/c
charged hadrons

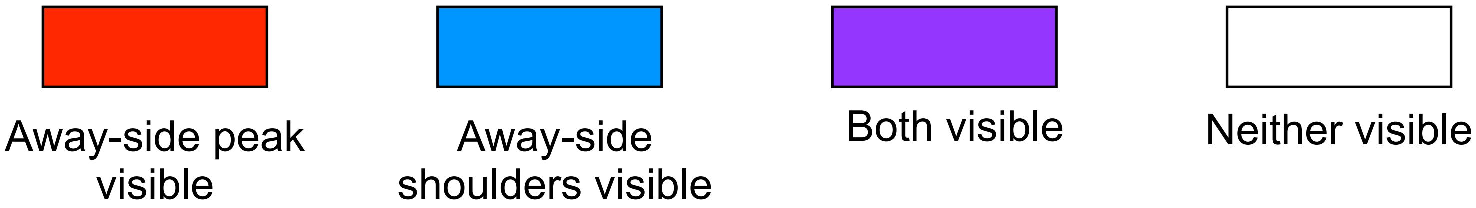


0-10%
30-40%
60-92%

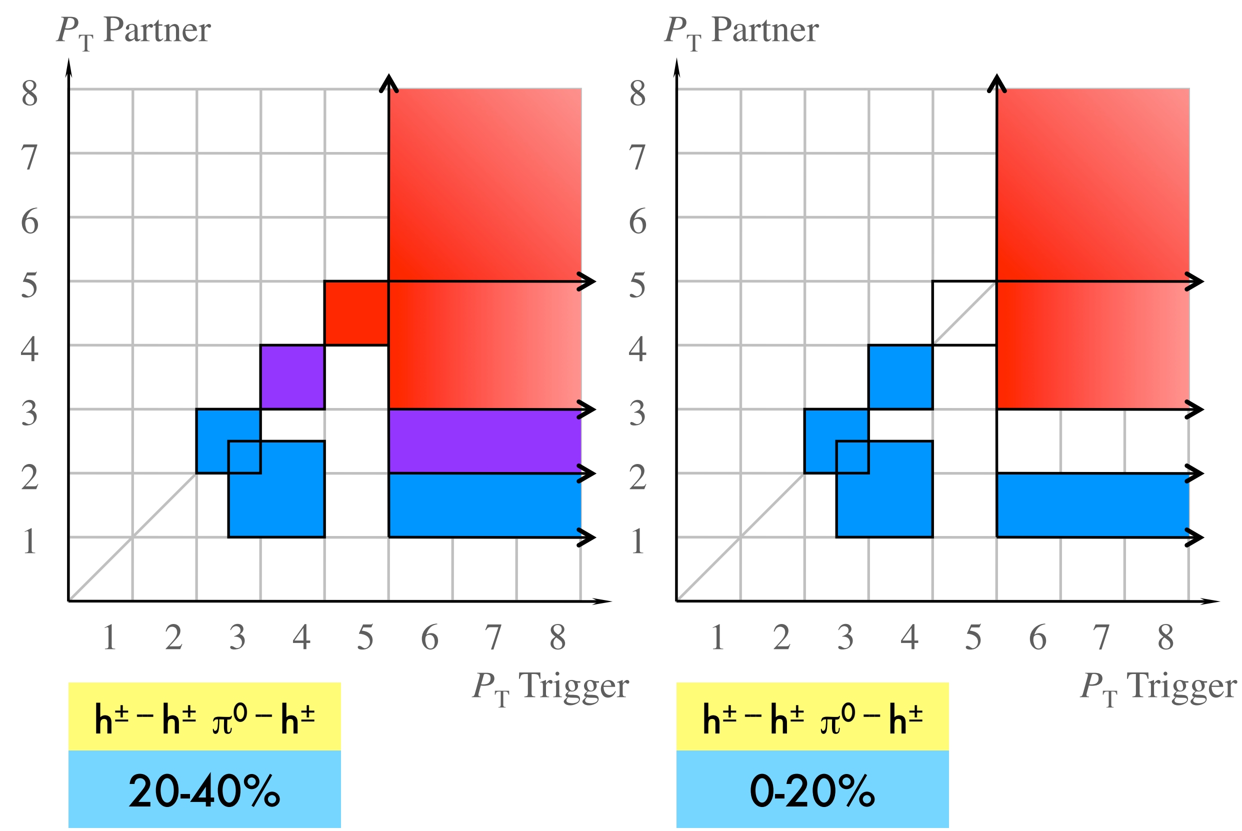


Away side Splitting Consistent with only N_{part} Dependence

Shape Summary



based on PHENIX Preliminary AuAu 200GeV



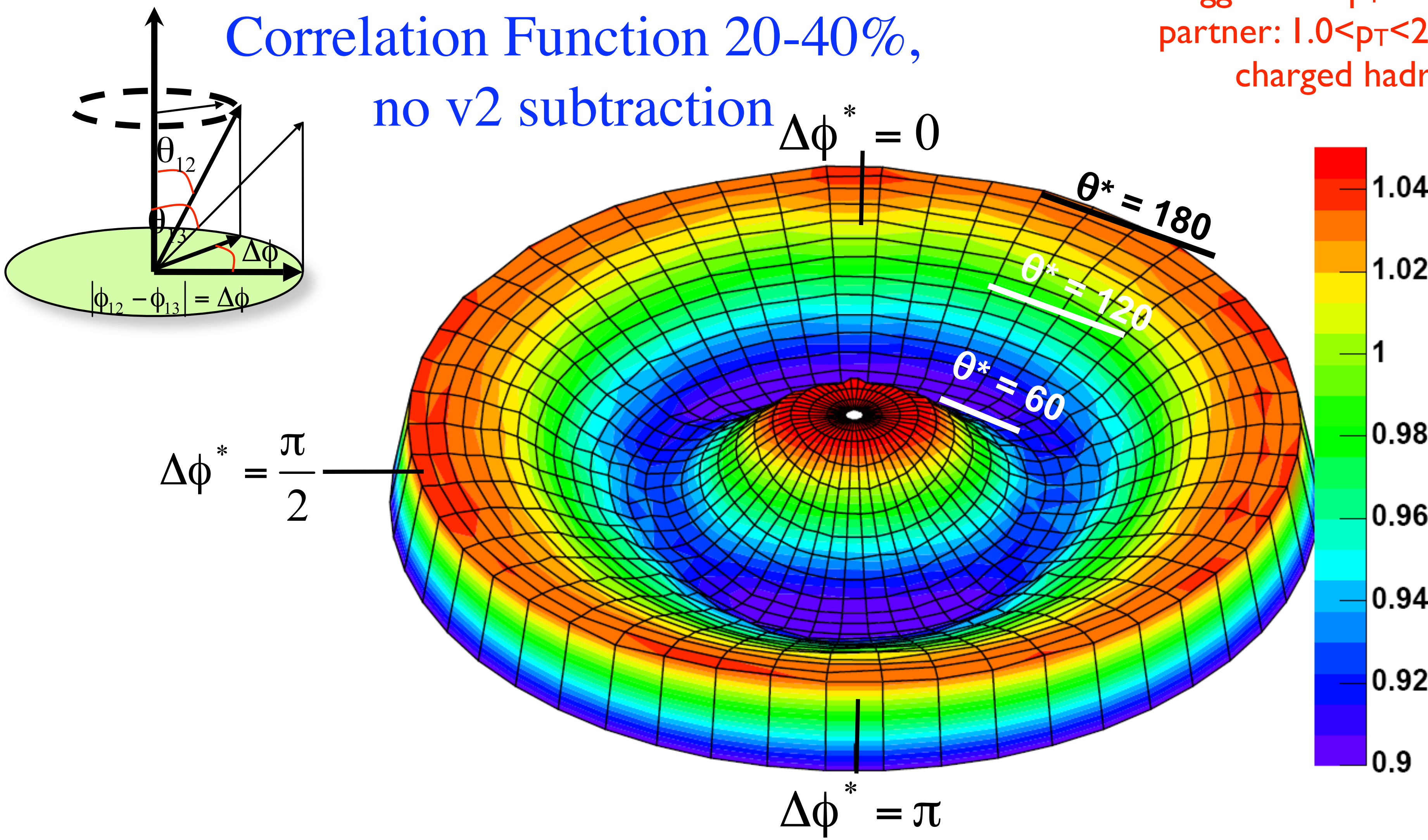
from P. Stankus CIPANP 2006

3 Particle Correlations

A Polar Representation

Correlation Function 20-40%, no v2 subtraction

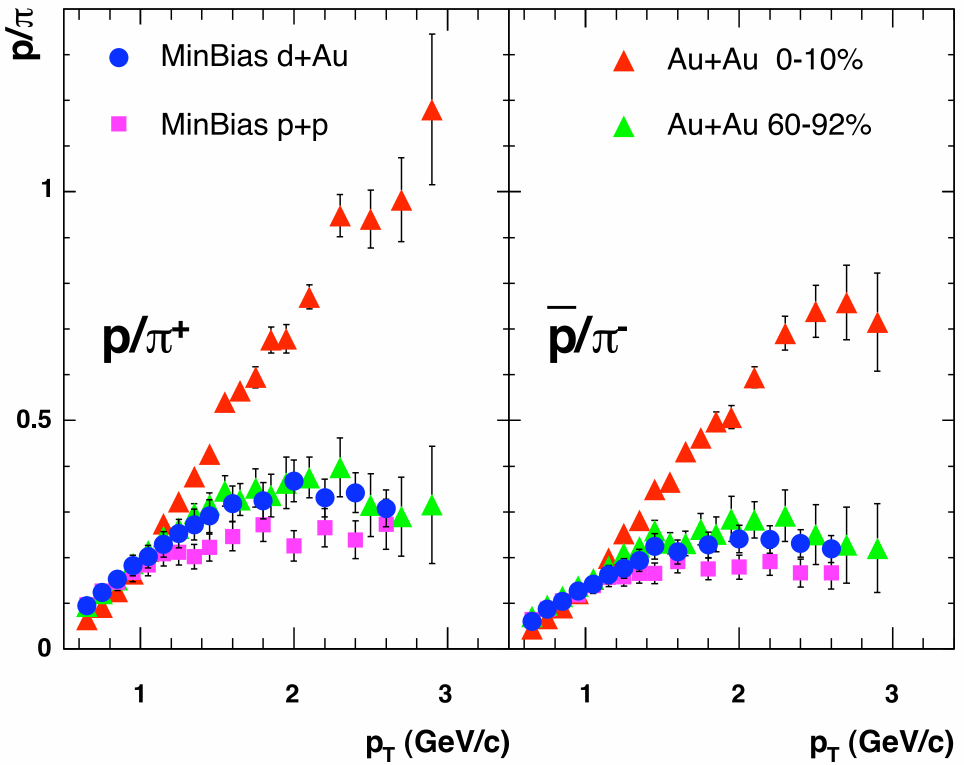
trigger: 2.5<p_T<4.0 GeV/c
partner: 1.0<p_T<2.5 GeV/c
charged hadrons



see NN Ajitanand's talk at Hard Probes next week

Same Side Correlations

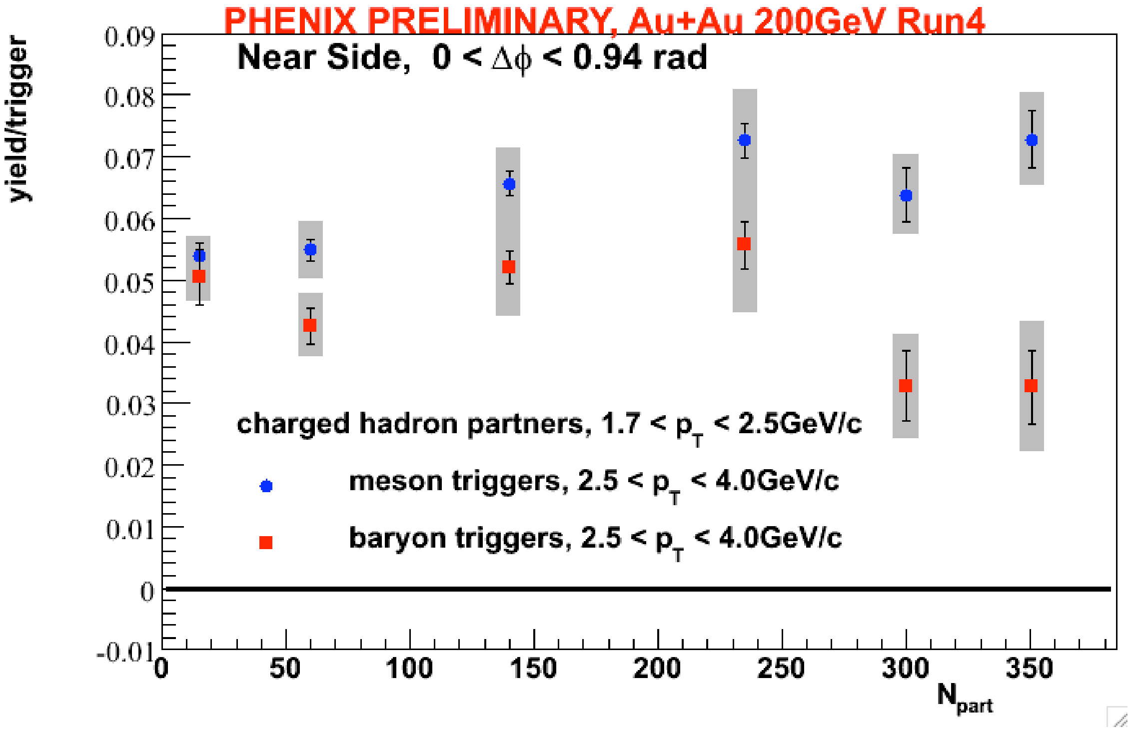
- Trigger particle is more likely to come from a hard scattering near the surface and have lost a little energy than to cor from the center and have lost a lot
  - Same side should be less modified
- Recombination: idea that partons close together in phase space combine to for final state hadrons
  - natural explanation for enhanced baryon production in heavy ion collisions
  - same side correlations with identifie particles can help disentangle recombination and hard processes



PHENIX, nucl-ex/0603010

Baryons from Jets?

- measure correlations in the region of baryon/meson difference
  - identify trigger as baryon (p, anti-p) or meson (π, K), partners are charged hadrons
- no difference between baryon & meson triggers until the most central collisions (>10%)
  - not the same centrality dependence as p/π ratio

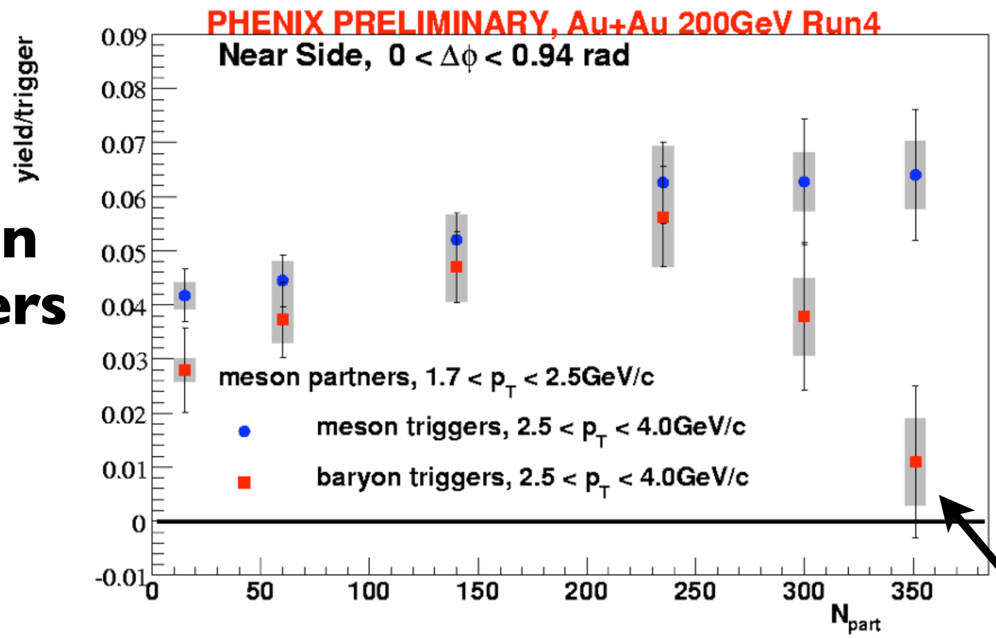


trigger: 2.5<pT<4.0 GeV/c
partner: 1.7<pT<2.5 GeV/c
charged hadron partners

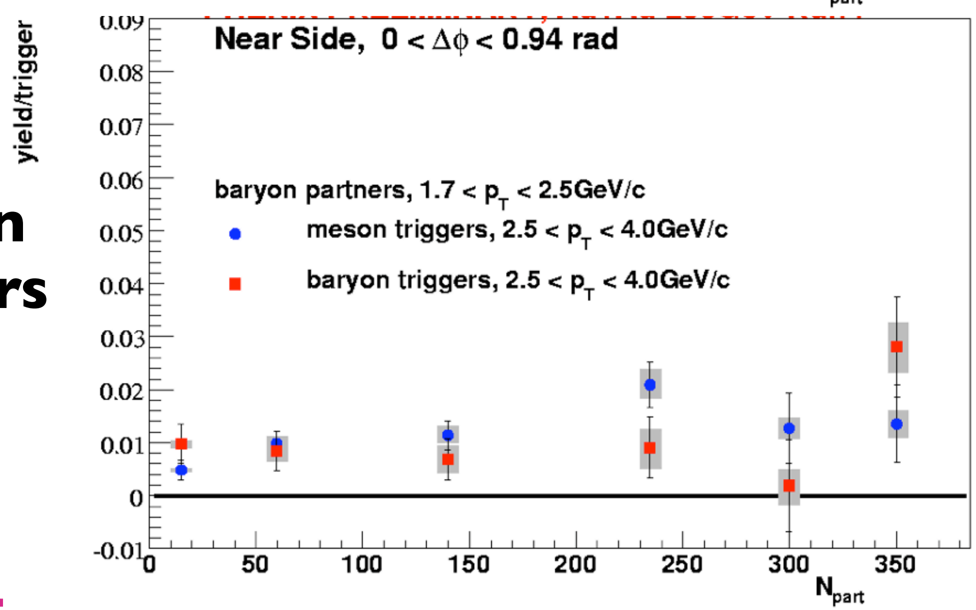
Both Particles Identified

trigger: 2.5<pT<4.0 GeV/c
partner: 1.7<pT<2.5 GeV/c

meson partners



baryon partners



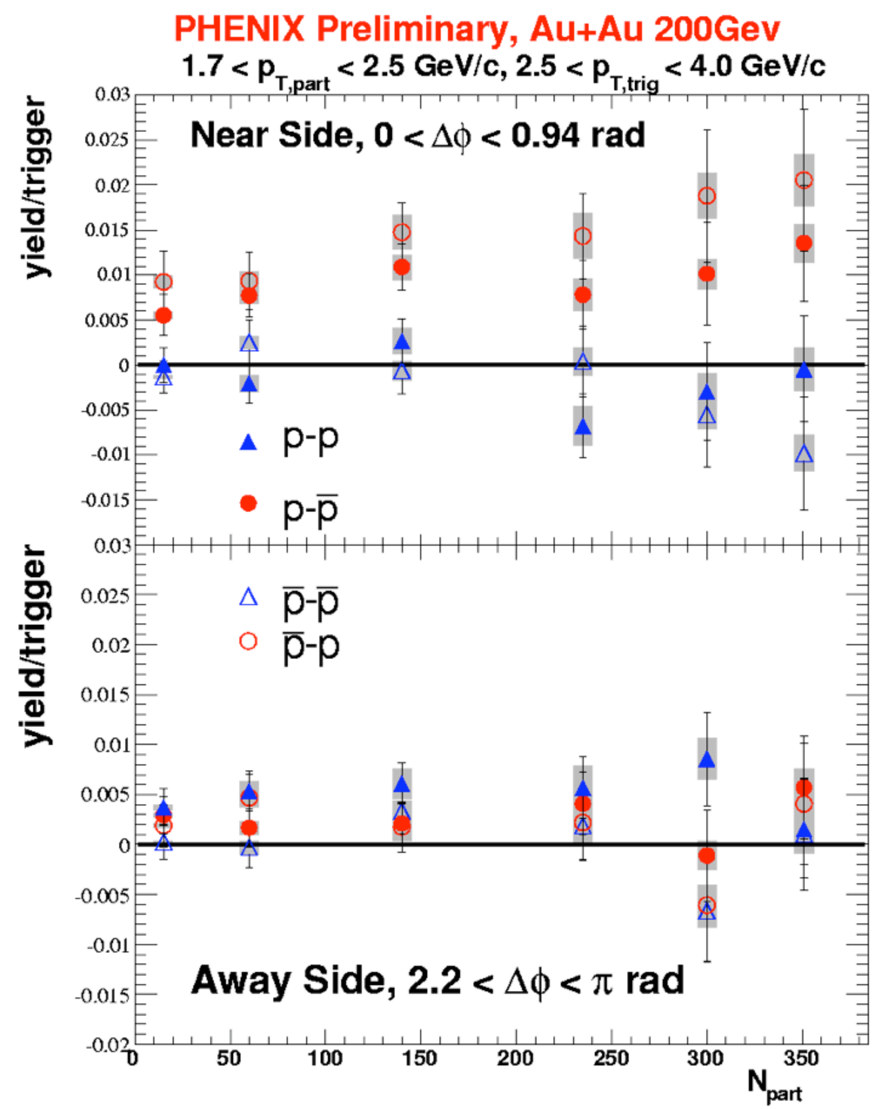
- big difference between baryon and meson triggers with meson partners, only in very central collisions
  - *is this recombination?*
- no significant differences with baryon partners

p & $\bar{p}$ Correlations

trigger: 2.5<pT<4.0 GeV/c
partner: 1.7<pT<2.5 GeV/c

Near Side

Away Side



Opposite Charge

p-$\bar{p}$ & $\bar{p}$-p

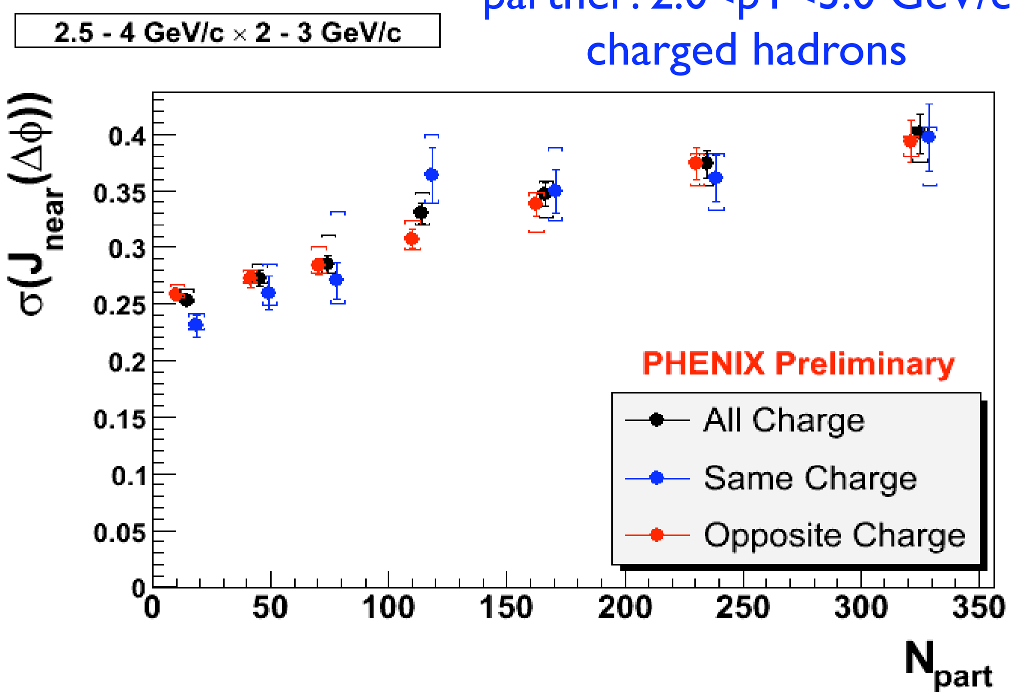
Same Charge

p-p & $\bar{p}$-$\bar{p}$

<u>Baryon number conservation in near side jet correlation at all centralities</u>

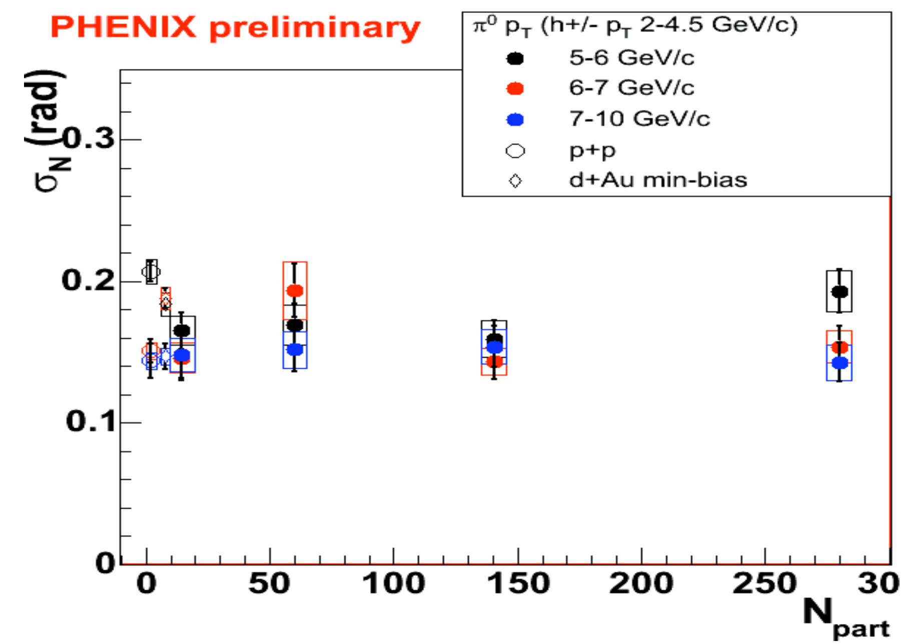
Near Side Jet Width

trigger: 2.5<pT<4.0 GeV/c
partner: 2.0<pT<3.0 GeV/c
charged hadrons



Near side jet
width broadens significantly
with centrality
at intermediate p_T

partner: 2.0<pT<4.5 GeV/c
π^0-charged hadrons

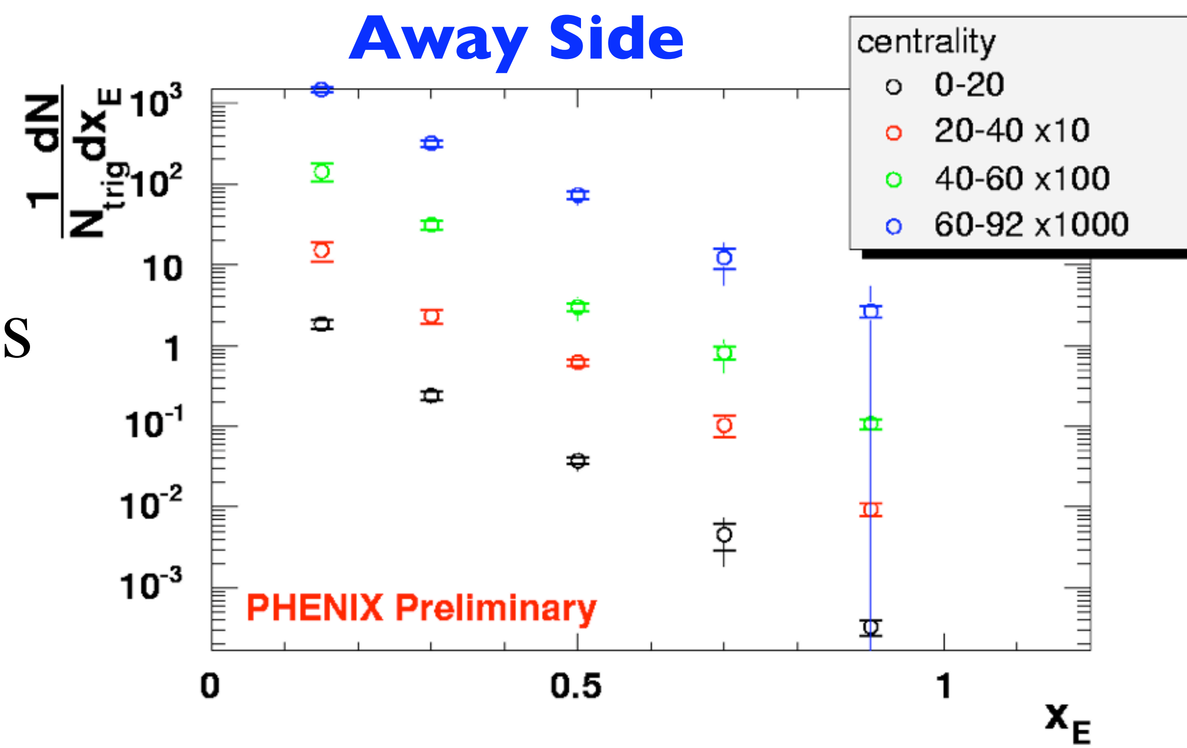


No centrality dependence
at high p_T

γ-Jet Correlations

- Direct γ - Jet correlations will allow measurement of the fragmentation functions
  - subtracting the π^0 contribution is hard, work ongoing in PHENIX--results soon

Inclusive γ trigger > 5GeV
Charged hadron partners



$x_E = p_{Ta} \cos\Delta\psi \,/\, p_{Tt}$

Conclusions

- **intermediate p_T is a great place to study interactions between the medium and hard probes**
- **robust dip/plateau in AuAu away side correlations**
  - dramatic and unexpected
  - many interesting theoretical ideas exist, need to understand how to distinguish among them experimentally
- **same side correlations are modified too**
  - baryon excess has hard scattering origin
  - near side correlation width increases with centrality
  - surface emission is too simplistic at intermediate p_T

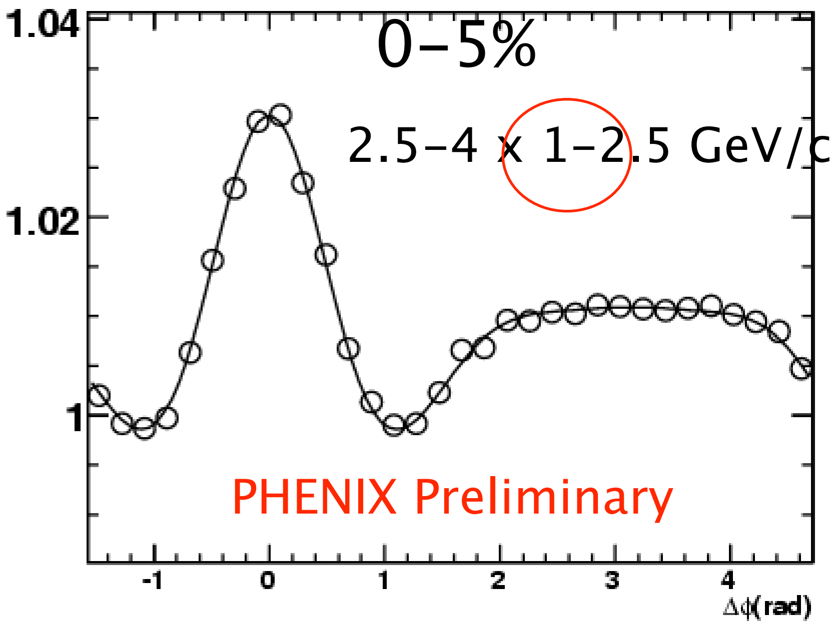
Going Forward

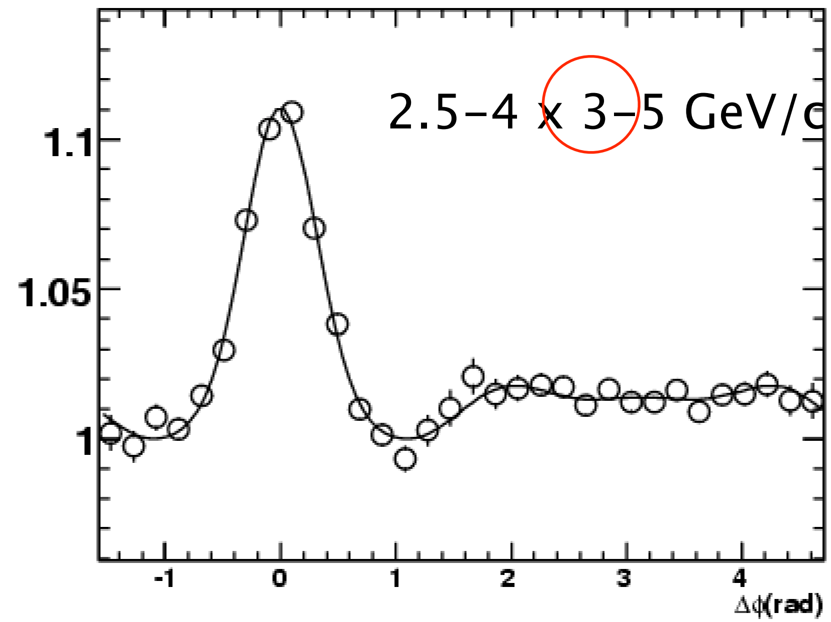
- We know jets are strongly modified by the medium
  - need to quantify the strength of the away side modification
  - need to fill in the centrality, particle type, system size, energy and p_T dependence of the correlation variables
- How do we extract the most information about the medium?

BACKUP

How Robust is the Dip?

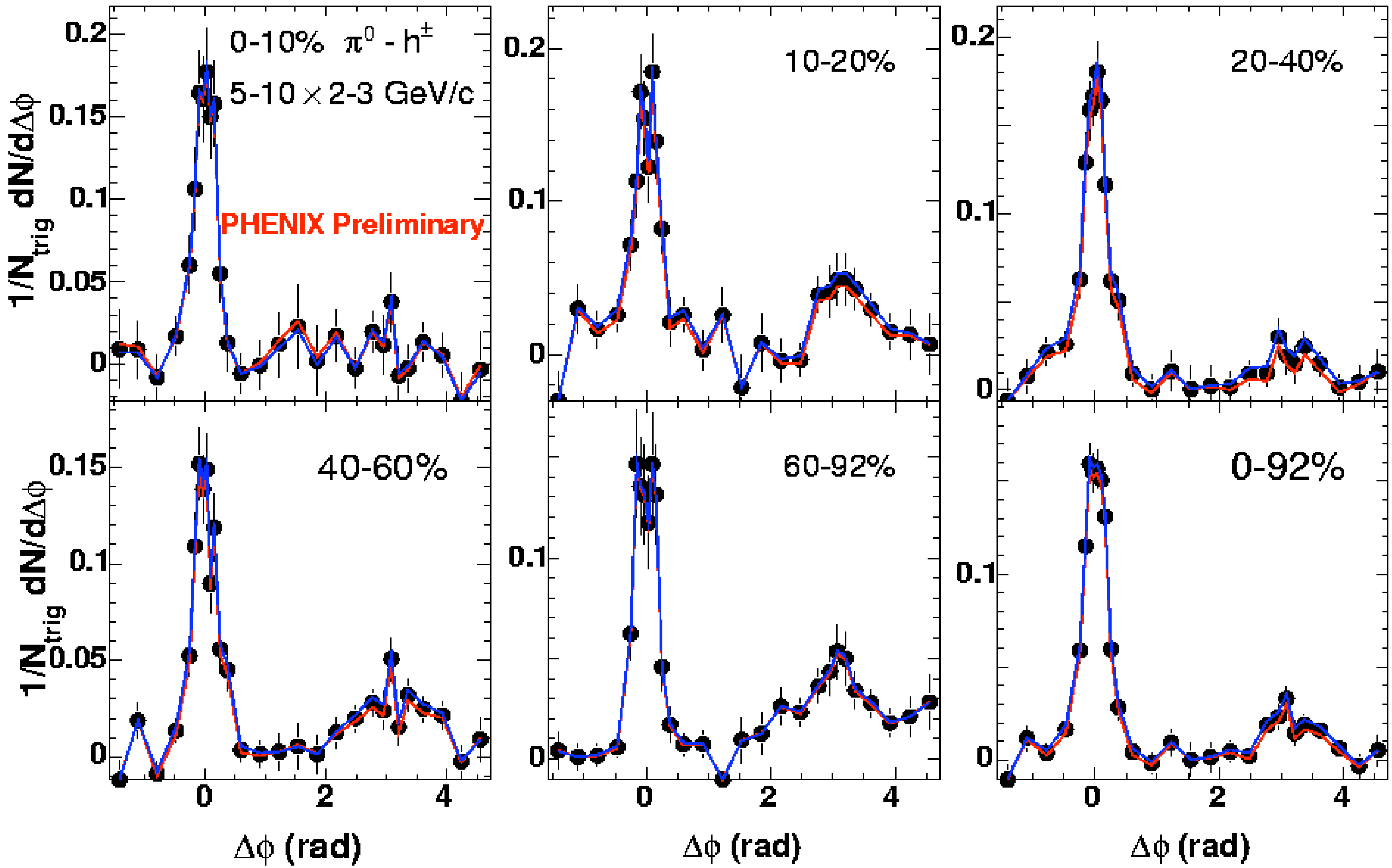
$$C(\Delta\phi) = \frac{dN_{pair} / d\Delta\phi}{dN_{mix} / d\Delta\phi}$$





Raw Correlation Function (NO v_2 subtraction) is Flat

AuAu High p_T



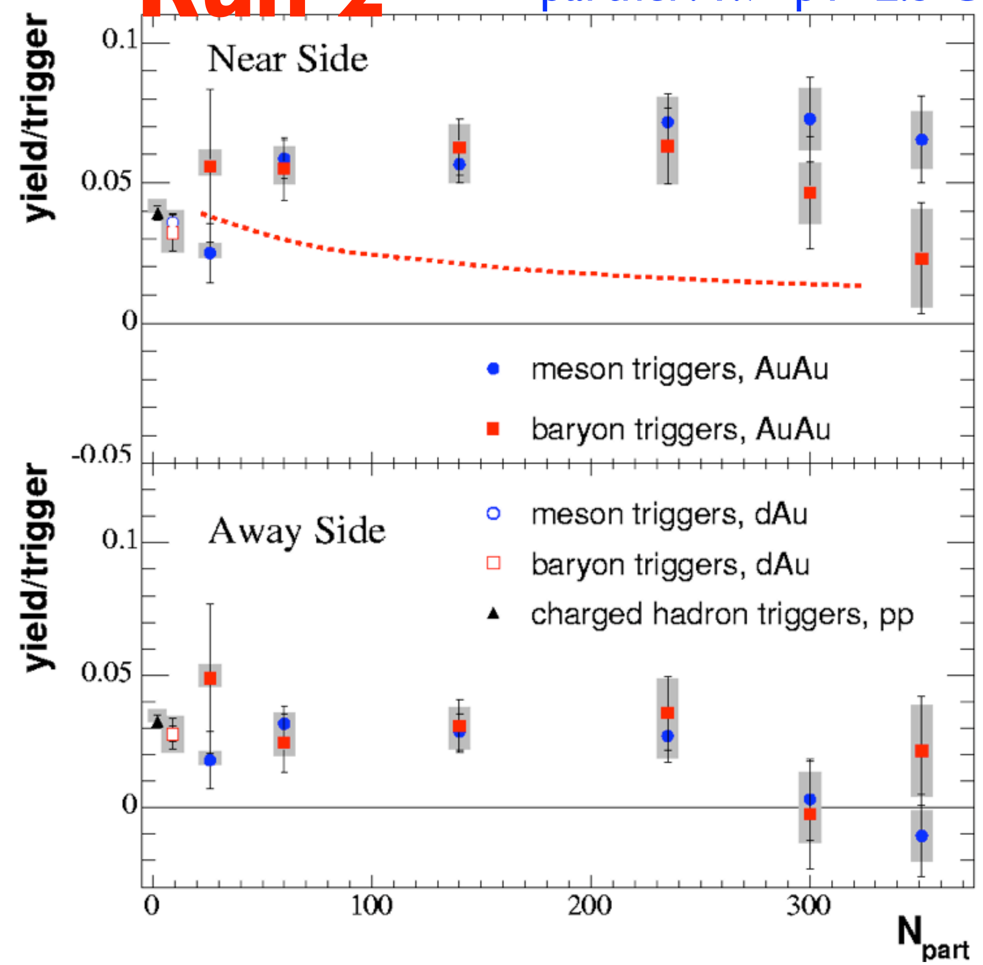
0-10% π⁰ - h±
5-10 × 2-3 GeV/c
PHENIX Preliminary
10-20%
20-40%
40-60%
60-92%
0-92%
1/N_trig dN/dΔφ
Δφ (rad)

baryons from jets?

- If baryon excess has nothing to do with hard scattering the extra baryons should have no jet like partners
    - the red line dilutes the pp yield per trigger by the fraction of baryons which are assume to be from the non-jet source
    - the data are above the line so some fraction of the baryon excess must be due to hard scattering

trigger: 2.5<pT<4.0 GeV/c
partner: 1.7<pT<2.5 GeV/c

Run 2



PHENIX, PRC 051902(R) 2005